of the original claims and the original description as shown in the following table, and do not introduce any new matter. Entry and consideration of the new claims are respectfully requested.

New Claims	16	17	18	19	20	21	22
Original Support	Cl.1,2,6	Cl.3	Cl.4	Cl.7	Cl.3,4; pg.11, ln.1-28	Cl.5	pg.10, ln.24-26

2) Action on this Continued Prosecution Application was suspended for three months from the CPA filing date of March 18, 2002. In a Telephone Interview on June 18, 2002, the Examiner indicated that he would next take up this application for examination, at the earliest, in the last week of June. Thus, the Examiner said he would enter and consider this Voluntary Amendment in connection with the first examination of this CPA Application. The Examiner's consideration is appreciated.

3) The Examiner's attention is directed to an Information Disclosure Statement being filed simultaneously by first-class mail, while this Voluntary Amendment is being filed by Telefax. Since the Information Disclosure Statement includes numerous references, it would not have been practical to file the Information Disclosure Statement by Telefax. For information purposes, a copy of the Information Disclosure Statement and Form PTO-1449 (without cited reference copies) is enclosed herewith. The Examiner is respectfully requested to consider the references, once received, and to return an initialed and signed copy of the corresponding Form PTO-1449, together with the next official communication.

4) The Examiner is respectfully requested to indicate whether the proposed drawing correction of October 3, 2001, and the supplemental drawing correction of October 26, 2001 have been approved. Corrected formal drawings will then be filed.

5) The Examiner is further respectfully requested to indicate whether the Voluntary Supplemental Amendment of October 3, 2001 has been received and entered.

6) The Examiner is respectfully requested to review and consider the following remarks in connection with the first examination of the new claims 16 to 22 in this CPA Application.

7) In the general characteristics of a light emitting semiconductor device, an operating current and an optical output have a linear relationship with respect to each other. When the operating current is increased, the optical output is also increased in proportion. However, a light emitting semiconductor device has a lifetime that is inversely proportional to the square of the current. Thus, if it operates on high currents, it has a reduced lifetime. Due to such a characteristic, it is desirable for a light emitting semiconductor device to be able to operate on low currents while providing high optical outputs.

8) The general background of the prior art is as follows.

One example of a conventional light emitting semiconductor device has an upper electrode formed of a single Au layer. If the Au film is small in thickness (e.g., approximately 5 nm),

then a current does not spread laterally to a sufficient extent and a reduced quantity of light is externally output. On the other hand, if the Au film is increased in thickness (e.g., approximately 20 nm) to laterally spread the current, then optical transmittance would be reduced. For example, for light of a wavelength of 500 nm a transmittance of 37% is obtained and 63% of light would be absorbed by the Au.

Another example of a conventional light emitting semiconductor device has an upper electrode formed of a transparent conductive film. The transparent conductive film (for example In_2O_3 · ZnO_2) is n-type semiconductor and forms a pn-junction with an underlying p-type semiconductor layer. An ohmic contact thus cannot be obtained therebetween, and a bandgap contributes to an increased electric resistance.

9) A general discussion of the present invention is as follows.

The present invention is based on a light emitting semiconductor device having a p-type semiconductor layer formed of a ZnSe-, ZnTe-, or BeTe-based semiconductor layer..An object of the invention is to enable the device to operate on a small current while providing a high optical output.

The present invention is based on a semiconductor light-emitting device including a substrate having a back surface provided with an n-type lower electrode, a light-emitting layer provided on the substrate, a p-type semiconductor layer provided on the light-emitting layer, and an upper electrode provided on the p-type semiconductor layer. The inventive device has the following special characteristics:

a) the p-type semiconductor layer is a semiconductor layer selected from the group consisting of ZnSe-, ZnTe-, and BeTe-based semiconductor layers; and

b) the upper electrode includes an Au thin film positioned in contact with the p-type semiconductor layer and an n-type transparent conductor film formed on the Au thin film.

These features provide the following functions and effects:

c) The ZnSe-, ZnTe- or BeTe-based semiconductor layer is susceptible to high temperature and there is a possibility that if it undergoes a high-temperature thermal treatment its characteristics will be impaired and it can thus no longer be used. The present inventors have confirmed that these semiconductor layers and the Au thin film can provide a good ohmic contact without a high-temperature thermal treatment.

d) The n-type transparent conductor film on the Au thin film can laterally extend or spread a current to provide an increased quantity of light output.

e) For the same operating voltage, the upper electrode having a 2-layer structure formed of the n-type transparent conductor film (for example of 90 nm in thickness) and the Au thin film (for example of 3 nm in thickness) allows an optical output approximately 1.4 times greater than that achieved with an upper electrode formed of a film of a single Au layer (for example of 20 nm in thickness). In order for the device with the former electrode to provide the same optical output as a device with

the latter electrode, the former device can operate on a reduced current in comparison to the latter device. It can thus have a prolonged lifetime.

10) The pertinent prior art references will now be discussed in comparison to the present invention. Applicants' prior remarks in the Responses of October 3, 2001 and February 18, 2002 are incorporated herein by reference and reasserted, to the extent that they apply to the present claims and references. The Examiner is requested to reconsider applicants' prior remarks, and to consider the following additional remarks.

In the previous Final Office Action the Examiner cited the following references: Ishibashi (U. S. 5,617,446); Kazuyoshi (JP 06-318406); Woodard (U. S. 6,255,003); and Mei (U. S. 6,107,641).

Ishibashi discloses forming an upper Au electrode (13, 14) on a p-type semiconductor layer (12). Ishibashi's upper electrode is formed only of an Au layer. Ishibashi fails to disclose forming an n-type transparent conductor film on the Au layer.

Kazuyoshi discloses that sputtering is used to form a transparent conductor film on a glass substrate. It is a glass substrate that the transparent conductor film contacts, and a pn-junction is thus absolutely not involved. Kazuyoshi's upper electrode is formed only of a transparent conductor film. Kazuyoshi fails to disclose using an Au film as a component of the upper electrode.

Neither Ishibashi nor Kazuyoshi disclose using as an upper electrode a structure formed of two layers of different types of material. In particular, there is not found in the references

a description suggesting a structure formed of the two layers of an Au film and an n-type transparent conductor film.

Woodard discloses that on a substrate (102) a gold layer (104) is formed and thereon a silver layer (106) is further provided. This structure formed of a stack of layers does not function as an upper electrode of a light emitting semiconductor device.

11) Referring to the Information Disclosure Statement being filed today by mail (of which a copy is enclosed herewith for reference), the Examiner is requested to consider the following references: Japanese Patent Laying-Open No. 10-308534 (Miki); Japanese Patent Laying-Open No. 11-87772 (Miki); and Japanese Patent Laying-Open No. 11-121804 (Miki).

These Miki references all disclose a light emitting semiconductor device based on GaN-based compound semiconductor material. For example, please refer to Fig. 3 of JP 10-308534, which shows a light emitting semiconductor device having on a p-type GaN layer (9), a translucent electrode having an Au layer (10) in contact with layer (9) and an Ni oxide layer (11) formed on layer (10).

A thin film simply formed of an Au layer and an NiO layer on a p-type GaN layer has a dark gray color presenting a metallic luster. It is hardly translucent. Accordingly, the thin film is subsequently subjected to a high-temperature thermal treatment to allow the electrode to have a bluish dark gray color and to become translucent. In the high-temperature thermal treatment, a substrate is held for example for ten minutes in an ambient

containing 1% of gaseous oxygen and having a temperature of 500 degrees centigrade. This treatment also serves as a heat treatment for obtaining an ohmic contact between an electrode and a semiconductor (paragraph 0027).

In comparison to the Miki references, the present invention provides a p-type semiconductor selected from the group consisting of ZnSe-, ZnTe-, and BeTe-based semiconductor layers, whereas Miki provides a p-type semiconductor layer formed of a Group III-V compound semiconductor layer represented by GaN. For example, JP 10-308534 describes in paragraph 0037 that GaN can be replaced with GaAs, GaP, InGaAs, AlInGaP, or the like. These are all Group III-V compound semiconductors and thus distinguished from ZnSe, ZnTe, BeTe and other similar Group II-VI compound semiconductors. Also, the present invention provides an Au film in contact with a ZnSe-, ZnTe-, or BeTe-based semiconductor layer, whereas Miki provides an Au film in contact with a GaN-based semiconductor layer.

12) It would not have been obvious to modify the teachings of Miki to arrive at or suggest the present invention.

Miki discloses a GaN doping level of approximately 10^{17}, which is relatively highly resistive. Accordingly, the GaN layer needs to underlie an Au film of some thickness to provide a sufficient ohmic contact therebetween. Simply depositing the Au film does not provide a sufficient ohmic contact and it needs to undergo a high-temperature thermal treatment as mentioned above. Furthermore, the Au film underlies a translucent metal oxide, which is formed of a metal stacked on the Au film which is then

subjected to a high-temperature thermal treatment in an ambient of oxygen.

The high-temperature thermal treatment is provided for example at no less than 300 degrees centigrade for one minute, as recited in claim 11 of JP 10-308534. GaN can endure high temperature and its characteristics are thus not impaired even by a high-temperature thermal treatment of no less than 300 degrees centigrade.

On a premise that a high-temperature thermal treatment is performed in an ambient of oxygen to provide a metal oxide and a sufficient ohmic contact, Miki deposits a first metal layer (e.g., an Au film) and a second metal layer (e.g., an Ni film) on a GaN layer.

In comparison to the teachings of Miki, it is known that ZnSe, as well as ZnTe and BeTe, (hereinafter ZnSe will be referred to representatively) is susceptible to high temperature. If it is exposed to high temperatures of no less than 300 degrees centigrade, its characteristics are impaired and it can no longer be used. It is further known that ZnSe is also susceptible to oxygen. If it is exposed to oxygen the former immediately reacts with the latter and they together form an oxide.

On a premise that a high-temperature thermal treatment is performed in an ambient of oxygen to provide a metal oxide and a sufficient ohmic contact, Miki provides an Au film on a heat-resistant, GaN-based semiconductor layer and further provides a metal oxide thereon.

The heat resistance of a GaN semiconductor layer is significantly different from that of a ZnSe-based semiconductor layer.

Miki's upper electrode is formed of an Au film and a translucent metal oxide on the premise that it undergoes a high-temperature thermal treatment in an ambient of oxygen. Those skilled in the art would not have been motivated to apply Miki's upper electrode to a ZnSe-based semiconductor layer, which cannot endure high-temperature thermal treatment and is in addition susceptible to oxygen.

The present inventors have noted a ZnSe doping level of no less than 10^{19} and conducted a variety of experiments. The present inventors have confirmed that an ohmic contact can be obtained without a high-temperature thermal treatment or an Au film having a large thickness, and have found that stacking an Au film on a p-type ZnSe-based semiconductor layer is practically possible.

As has been described previously, Miki fails to disclose or suggest the following features of the present invention:

a) the p-type semiconductor layer is a semiconductor layer selected from the group consisting of ZnSe-, ZnTe-, and BeTe-based semiconductor layers; and

b) the upper electrode includes an Au thin film positioned in contact with the p-type semiconductor layer and an n-type transparent conductor film formed on the Au thin film.

If Miki's light emitting semiconductor device would have the GaN simply replaced by ZnSe, then such a ZnSe-based semiconductor layer that undergoes a high-temperature thermal treatment would have impaired characteristics and the device would no longer be useable as a semiconductor device. Those skilled in the art

would not have been motivated to modify Miki's light emitting semiconductor device, which is subjected to a high-temperature thermal treatment in an ambient of oxygen, by replacing heat-resistant GaN with less heat-resistant ZnSe.

13) The dependent claims recite additional features that further distinguish the invention over the prior art, for example as follows:

Claim 17 defines that the Au thin film has a thickness of 1 nm to 3 nm. A thinner Au film contributes to higher transmittance. To provide a sufficient ohmic contact between the Au film and an underlying p-type semiconductor layer, however, the Au film is required to have a thickness of 1 nm to 3 nm. JP 10-308534 describes that a thin metal film is reduced in thickness to be more translucent. The reference, however, is on the premise that a high-temperature thermal treatment is performed in an ambient of oxygen, as has been described above, and if the Au film has a thickness of approximately 2 nm, ball-up may result.

JP 10-308534 only describes in paragraph 0005 that to obtain a transmittance of 90% the film having a thickness of approximately 2 nm is required. The reference does not give consideration to any other conditions. The thickness of an Au film used in a light emitting semiconductor device depends for example on the material(s) of an underlying semiconductor layer, the material(s) of an overlying semiconductor layer, and conditions for production, such as the presence/absence of a heat treatment. As such, the 2-nm thick Au film coincidentally described in JP

10-308534 would not be applied to a light emitting semiconductor device of a completely different type.

Claim 18 defines that the n-type transparent conductor film is In_2O_3 - 10 wt.% ZnO. It is not well known in the prior art to arrange an In_2O_3 - 10 wt.% ZnO, n-type transparent conductor film on an Au film as an upper electrode provided on a ZnSe-based, p-type semiconductor device.

Claim 19 recites that to obtain the above-described multilayer structure, laser ablation is used to form the In_2O_3 - 10 wt.% ZnO layer.

Claim 20 recites that the Au film has a thickness of 2 to 3 nm and that the n-type transparent conductor film is In_2O_3 - 10 wt.% ZnO of 180 to 200 nm in thickness. This feature allows an electrode to operate on a low voltage to provide a high optical output.

Claim 21 recites that the n-type transparent conductor film has a multilayer structure including an upper layer and a lower layer, the lower layer having a flattened surface, and the upper layer having an uneven surface. The lower layer of the transparent conductor film having a flat surface extends or spreads a current, and the upper layer having an uneven surface contributes to an increased quantity of light output.

Claim 22 recites that the n-type transparent conductor film is deposited at room temperature. Since the n-type transparent conductor film is deposited at room temperature on the Au film, the ZnSe-, ZnTe- or BeTe-based semiconductor layer, susceptible to high temperature, can have its characteristics maintained

satisfactorily. It is known that an In_2O_3- ZnO-based transparent conductor film deposited at room temperature is amorphous.

According to Miki, a translucent metal oxide (e.g., NiO) is formed of a metal deposited on an Au film and oxidized in a high-temperature thermal treatment performed in an ambient of oxygen. Furthermore, Miki's translucent metal oxide, formed in a high-temperature thermal treatment performed in an ambient of oxygen, is structurally distinguished from the n-type transparent conductor film of the present invention. The n-type transparent conductor film of the present invention is deposited at room temperature and it is thus amorphous.

In the present invention the fact that a ZnSe-based semiconductor layer is susceptible to heat and oxygen is considered and an n-type transparent conductor film is accordingly deposited on an Au film at a room temperature. This feature is not disclosed in any of the references. The structure formed of a stack of an In_2O_3 - 10 wt.% ZnO layer, an Au film and a ZnSe-based p-type semiconductor layer, had been unknown until the present application was filed.

14) The Information Disclosure Statement being filed simultaneously by mail further includes references supporting the above discussed patentable distinctions between the invention and the prior art, as follows.

<u>Documents describing a GaN Carrier Concentration</u>: Reference AB2 : "GaN and Related Materials II" issued by Gordon and Breach Science Publishers, describes on page 52 "semi-insulating, n-type, and p-type GaN and AlGaN have been grown by MOCVD and

MBE. Electron concentrations from 7 x 10^{16} cm^{-3} to 10^{19} cm^{-3} and hole concentrations up to 5 x 10^{18} cm^{-3} have been achieved." According to this reference, the p-type GaN's maximal hole concentration is to 5 x 10^{18} cm^{-3}. With such a carrier concentration, depositing a metal does not help to provide ohmic contact if it does not undergo a heat treatment. Reference AY "Ion implantation doping and isolation of GaN" issued by the American Institute of Physics, is cited in reference AB2, denoted as [38].

<u>Documents describing ZnSe carrier concentration</u>: Reference AV "Graded band gap ohmic contact to *p*-ZnSe" issued by the American Institute of Physics, describes on page 3160, left column "free-hole concentrations approaching 10^{19} cm^{-3} were easily obtained (the highest reported to date), while good crystalline quality, as revealed by x-ray rocking curves and photoluminescence measurements, was maintained." ZnSe-based devices generally employ a ZnSe/ZnTe or ZnSe/BeTe superlattice electrode. The device has an outermost surface of ZnTe for ZnSe/ZnTe or BeTe for ZnSe/BeTe. These semiconductors have a carrier concentration exceeding 10^{19} cm^{-3}. With such a carrier concentration it is not necessary to provide a heat treatment. Reference AA2: "Novel beryllium containing II - VI compounds: basic properties and potential applications" issued by the Journal of Crystal Growth, is also pertinent on this point.

<u>Documents evidencing that ZnSe is susceptible to oxygen</u>: Reference AZ: "Nanometer scale surface clustering on ZnSe epilayers" issued by the American Institute of Physics, describes that a surface reacts with oxygen and it is covered by SeO_2. In other words, the document describes that ZnSe is susceptible to

oxygen. Reference AW: "Analysis of the oxidation of polycrystalline zinc selenide by spectroscopic ellipsometry and photothermal deflection spectroscopy" issued by Elsevier Sequoia, describes that an oxide is produced through UV illumination.

Document disclosing an In_2O_3-ZnO-based amorphous transparent conductor film: Reference AX: Display Monthly, March 1998, pages 15-20, describes on page 20 that an IDIXO thin film deposited at room temperature can provide a stable amorphous conductor film.

15) In view of the above remarks, favorable consideration and allowance of this CPA Application, including all present claims 16 to 22, are respectfully requested.

Respectfully submitted,

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CERTIFICATE OF FAX TRANSMISSION:

I hereby certify that this correspondence with all indicated enclosures is being transmitted by telefax to (703) 308-7722 on the date indicated below, and is addressed to: Assistant Commissioner for Patents, Washington, D. C. 20231.

Walter F. Fasse 6/18/02

Walter F. Fasse - DATE: June 18, 2002

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